A 3650 – 1996 University of Wisconsin Extension Publication

New Standards for Sizing Milklines

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A new standard for construction and performance of milking systems has been approved and published by the American Society of Agricultural Engineers (ASAE S518). It includes major changes in the recommended number of milking units for milklines. These changes are based on research conducted at the University of Wisconsin-Madison, Milking Research and Instruction Laboratory.

New performance standard

The new standards now specify a minimum performance criterion rather than a specified number of milking units on a milkline. The performance standard for acceptable vacuum stability in the milkline is not more than 0.6" Hg (2 kPa) drop in milkline vacuum below the receiver vacuum during normal milking conditions.

The basis for this performance standard is that milk should flow in the lower part of the pipeline with a clear continuous space above for the much larger volume of air to pass over it during milking. This flow condition is known as stratified flow. Slug flow occurs whenever slugs of milk fill the entire cross-section of the milkline (Fig 1).

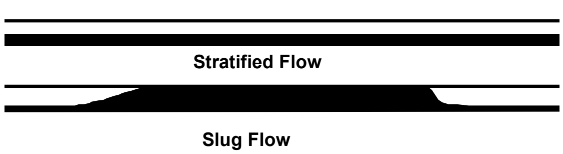

Figure 1. Cross-section of milkline showing stratified and slug flow.

Slug flow conditions almost always induce transient drops in milkline vacuum greater than 0.6" Hg whereas milkline vacuum almost always remains stable within 0.6" Hg of the receiver vacuum under stratified flow conditions. The new performance standard assures that the milkline will not slug under normal operating conditions.

Normal milking conditions are considered to include unit attachment and detachment and liner slips. A milking unit fall-off is **not** considered to be a condition of normal milking. Occasional slugs in the milkline are almost unavoidable when a large volume of air is admitted, such as when a milking unit falls off. Unit fall-off should be a rare event in a reasonable maintained and operated milking system. These normal, slug-free conditions should occur for at least 95% of the milking time for the herd. And an occasional slug should not be regarded as evidence of a system failure.

A milkline slug will produce a small and momentary drop in claw vacuum beyond the vacuum fluctuations normally occurring in any claw. A momentary vacuum drop is not likely to adversely affect milking performance, or increase the risk of mastitis. Frequent slugging in the milkline may result in lower mean claw vacuum, however. This will have a similar effect on milking performance and milk quality as raising the milkline height by about 1 foot, i.e., slower milking and more liner slips. Slug flow conditions may also produce a marginal increase in the acid degree values in milk.

Design Guidelines for New Systems

While the emphasis of the new standard has shifted from a design specification to a performance standard, there is still a need for design guidelines for new systems. Example design guidelines are shown in Tables 1, 2, and 3.

Table 1. Maximum number of units per slope for looped milklines in milking parlors with careful operators.

Dia.			Slope		
	0.8%	1%	1.2%	1.5%	2%
2 in.	2	3	3	4	5
2.5 in.	6	6	7	9	10
3 in.	11	13	14	16	19
4 in.	27	30	34	38	45

Table 2. Maximum number of units per slope for looped milklines in milking parlors with typical operators.

Dia.			Slope		
	0.8%	1%	1.2%	1.5%	2%
2 in.	1	1	2	2	3
2.5 in.	4	4	5	6	8
3 in.	9	10	12	13	16
4 in.	24	27	31	36	41

Table 3. Maximum number of units per slope for looped milklines in Round-The-Barn highline systems.

Dia.			Slope	
	0.8%	1%	1.2%	1.5%
2 in.	2	3	3	4
2.5 in.	6	9	*	*
3 in.	*	*	*	*

The five most important design criteria for determining the minimum number of milking units on a milkline are: diameter and slope of the milkline, air admission into the milking system, peak milking rates of cows, and the rate of unit attachment.

Diameter. Increasing the pipeline diameter has the greatest single effect on carrying capacity. As shown in Tables 1, 2, and 3, doubling the milkline diameter increases the effective milk-carrying capacity of a milkline by at least nine times.

Slope. Milk flow is induced by gravity and by the air flowing over the milk surface. Increasing milkline slope increases the influence of gravity as a driving force causing milk flow. Increasing milkline slope reduces the risk of slug flow by reducing the average fill depth for any given milk flowrate. As shown in the example tables, doubling the milkline slope increases the effective milk-carrying capacity by 50% or more.

Regions of lower slope or "flat spots" in a milkline will reduce its effective milk-carrying capacity. The likelihood of milkline slugging is influenced more by such flat spots than by the overall average slope. The effective milk-carrying capacity is also reduced by excessive bends and other fittings which increase frictional losses. Compensation may be made by increasing the slope of a milkline in the region of bends and fittings, especially near the receiver where both the milk and air flowrates are highest.

Air admission. The velocity of the air moving over the milk is the main cause of slugging in milklines. The highest air flow rate and air velocity occur when intermittent or "transient" air is admitted during attachment and detachment of units, liner slips and unit fall-off. A design guideline of 7 cfm (200 L/min) for intermittent air flow is a reasonable allowance for liner slip and unit attachment for operators who take care to limit air admission while attaching milking units to the cow. For operators who do not follow good unit attachment practices, this allowance should be doubled.

The milking operators play an important role in helping to maintain vacuum stability by taking care to limit the amount of air admitted when they attach or detach milking units. When the milkline is looped the design transient airflow rate per slope can be halved because the air can flow to the receiver through both arms of the loop according to the easiest flow path. Significant benefits thus result from the reduction in the air flowrate per slope when milklines are looped.

Peak milking rates of cows. The average peak milking rate per cow and average rate of attaching milking units to individual cows are the two main factors which determine the maximum predicted milk flowrate in the milkline. Average peak flowrate for high-producing herds in the US are about 9 lb./min (4 L/min) per cow at present. A design value of 12 lb./min (5.5 L/min) per cow has been used to develop Tables 1, 2, and 3. This figure has been derived from field measurements and represents the fastest milking 5% of cows in the US. This higher figure was used to ensure that milking systems installed now will be adequate for milking high-producing herds into the next century. The average peak flowrate of cows in any herd can be measured in several ways (see side box).

Attachment Interval. The time between unit attachment plays a secondary role in determining the expected peak milk flow rate in the milkline. To further simplify the calculations and provide the most conservative estimates, Table 1 and 2 assume that all units are attached at the same instant in parlors. If the unit attachment interval is taken into account the allowable number of units per slope only for the 3 inch line at the highest slopes, and for the 4 inch line will increase slightly.

Evaluating Existing Systems

The new standards are meant to apply to new systems. They are therefore meant to be conservative, as new systems installed today should be designed to accommodate higher producing cows for the useful life of the system. For example, Tables 1 and 2 assume that units are attached instantaneously in parlors and that all cows will be at peak milk flow rate at the same time. Recommended techniques when a pre dip is used will result in an attachment interval of 15 to 30 seconds per unit. This method will result in better labor efficiency and reduced peak milk flow in the milkline than washing all udders and then returning to attach all units.

When evaluating an existing system the emphasis should be placed entirely on the performance of the system. If milkline carrying capacity is questioned, the first step in evaluating the system is to measure vacuum stability in the milkline and in the receiver during normal milking. This test should also be performed as a commissioning test of a new milking system.

The measurement in the milkline should be made by a direct connection to the first inlet on the milkline which is at least 3 feet (1 meter) from the receiver on the slope that is more heavily loaded. Ideally, the milkline and receiver measurements should be made simultaneously. This dynamic test should be run at least two complete turns in a milking parlor or during the time required to milk two cows with each milking unit on a round-the-barn pipeline system. Pay special attention to tests performed during unit attachment and removal. It is preferable to perform several test of 15 to 30 seconds duration each rather than a single test of several minutes duration. Several short test will help to identify the specific events which caused vacuum fluctuation.

The ASAE performance standard states that the milkline vacuum should not fall more than 0.6" Hg (2 kPa) below the vacuum level in the receiver during normal milking. An example vacuum recording made on a properly functioning system during milking, as units are being attached and detached, is shown in Figure 2. Most vacuum recorders will indicate the maximum and minimum vacuum recorded over the test interval. The vacuum fluctuation is taken as the maximum vacuum minus the minimum vacuum.

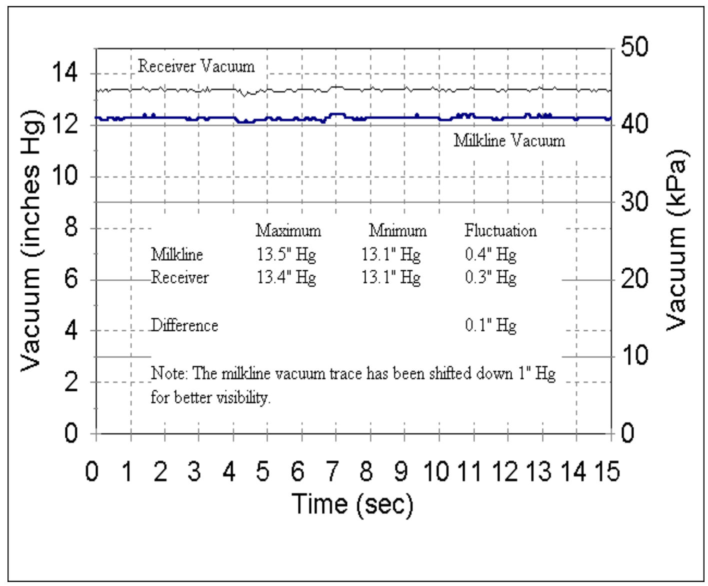

Figure 2. Vacuum recording for a properly functioning milking system.

In the recording illustrated in Figure 2, both milkline and receiver vacuum fluctuations are less than 0.6" Hg (2 kPa). The difference between the milkline vacuum fluctuation and the receiver vacuum fluctuation is the contribution to vacuum fluctuation caused by the milkline. If the difference in milkline and receiver fluctuations exceeds 0.6" Hg (2 kPa) it is likely that a slug has occurred in the milkline. The vacuum fluctuation in the receiver in Figure 2 is less than 0.6" Hg indicating that the effective reserve and regulator response are sufficient to cope with the amount of air admitted by the operators. The difference between the milkline and receiver fluctuations is also less than 0.6" Hg indicating that the milkline did not slug.

An example recordings made on a system with milkline slugging is shown in Figure 3. The vacuum fluctuation in the receiver is less than 0.6" Hg, indicating a properly functioning regulator and vacuum pump. The difference between milkline and receiver vacuum fluctuations is greater than 0.6" Hg, however, indicating the presence of a slug in the milkline.

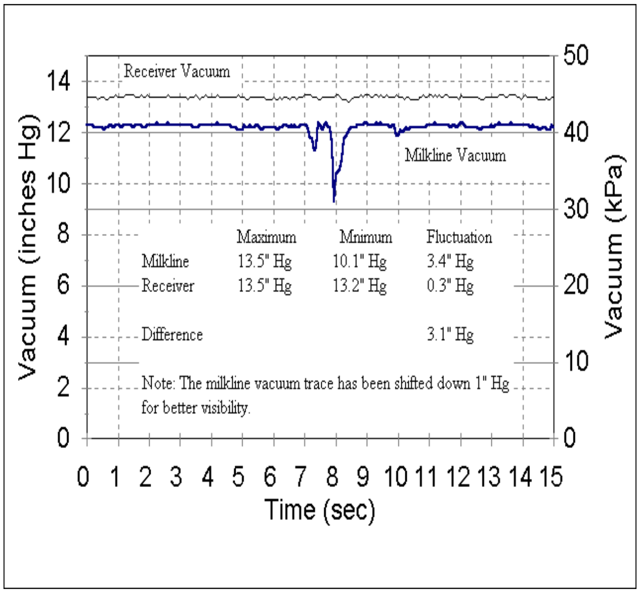

Figure 3. Example vacuum recording with a slugging milkline.

An example recording from a system with poor vacuum regulation and/or excessive air admission is shown in Figure 4. Both receiver and milkline vacuum drop by more than 0.6" Hg (2 kPa) when air is admitted (probably during unit attachment). The difference between the milkline and receiver vacuum fluctuations is not, however, greater than 0.6" Hg. This vacuum fluctuation is not caused by milkline slugging and can be reduced only by reducing the amount of transient air admission or by improving the effectiveness of vacuum regulation.

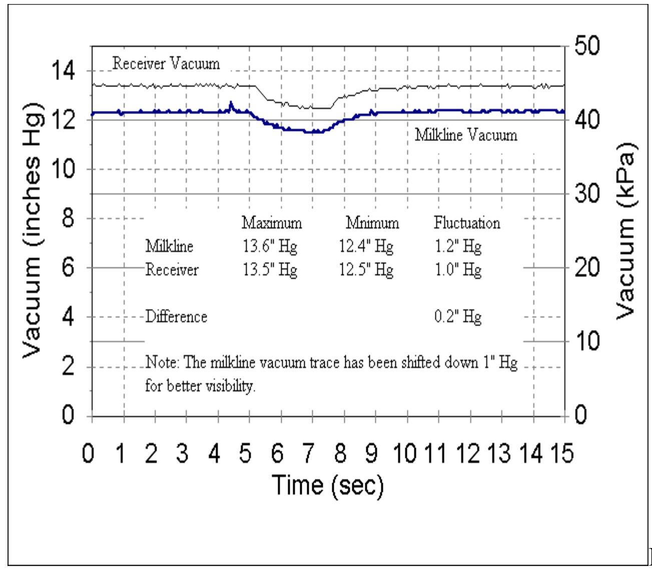

Figure 4. Example vacuum recording with no slugging and poor regulator response and/or excessive air admission.

If the milking system passes this performance test there is no reason to make changes. If the vacuum recordings indicate that slugging may be occurring, improvements should be made in the following order:

1. Improve operator technique to reduce the amount of air admission during unit attachment, detachment and normal milking. This will have little of no cost and significantly improve the vacuum stability in most systems.

2. Increase the slope of the milkline, especially near the receiver. If clearance is a problem, slope the line so that the minimum slope is near the high point of the system and slope increases toward the receiver. Slope should be maximum in the last sections of the line where most bends and fittings are located, as these account for much of the restriction to milk flow. Performance can also be improved by minimizing the number of bends and fittings in the milkline.

3. If steps 1 and 2 have been done correctly and the system still does not pass the performance test, the size of the milkline can be increased. If the milkline diameter is increased, the water volume and air injector settings must be adjusted to ensure that the system can be cleaned.